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Merchantable Volume and Weights of Mahoe in Puerto Rican Plantations

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SUMMARY

Mahoe (*Hibiscus elatus* Sw.), a fast-growing tree whose wood is considered valuable, is planted and managed primarily in the West Indies. Until now, volume and weight tables have not been available for the species. Data used in this paper were collected from 50 felled trees in a range of sizes from plantations across Puerto Rico. Using linear regression techniques, equations were derived to construct tables for merchantable bole volume, with and without bark, and green and dry weights of merchantable boles. A local volume curve is also presented that can be used to estimate merchantable volumes with bark from diameter measurements at breast height. Heartwood diameter can be predicted from inside-bark diameter and height on the stem.

INTRODUCTION

Hibiscus elatus Sw., commonly known as mahoe or blue mahoe, is native to Cuba and Jamaica. This upland tree is impressive with a straight, clean form and rapid growth. Its wood is of moderate density with a streaked metallic gray color, and it works easily (Chudnoff 1984). Mahoe is being planted and managed in its natural range and in a number of other tropical countries (Weaver and Francis 1988). Growth rates of mahoe have been reported for Hawaii (Whitesell and Walters 1976), Jamaica (Wadsworth 1960, Swabey 1940), Puerto Rico (Francis and Weaver 1988), and St. Lucia (Weaver and Lugo 1981, Ward and Charles 1982). Also, site quality (site index) curves from St. Lucia and Puerto Rico are available (Ward and Charles 1982, Mark and others 1988). A stand table for volume over bark per hectare based on basal area and average dominant height was developed for Grenada (Johnson 1985). However, no individual tree volume or weight tables have been published to date.

METHODS

Sample trees were chosen from plantations in five different forests and numerous plantations distributed throughout the moist, central area of Puerto Rico. Fifty trees were selected that ranged from 15 to 59 cm in diameter at breast height (d.b.h.); the commercial bole lengths ranged from 6 to 26 m. Commercial bole length was defined as the distance between the stump and a 10-cm bole diameter or an obstruction such as a major ramification that would render material above that point unmerchantable. Most trees tapered evenly to the minimum diameter. The d.b.h.'s were measured to the nearest 0.1 cm with a diameter tape. Then each tree was felled. Stump height was measured to the nearest 1.0 cm, and total height was measured to the nearest 0.1 m. Starting at the stump, diameters to the nearest 0.1 cm of the commercial bole were measured at 1-m intervals with calipers. The commercial bole length to the nearest 0.1 m and diameter to the nearest 0.1 cm at commercial height were also measured. Bark thickness was determined at each meter with a bark gauge. Disks 5 to 8 cm thick were cut from each tree at four of the 1-m intervals scattered up the bole. The disks were measured for thickness (nearest 0.1 cm), weighed, and then oven dried (85 °C) to constant moisture. After drying, the wood and bark were separated and weighed individually. Heartwood thickness and inside-bark diameter of the dry disks were also measured.

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Commercial volumes of the sample trees both with and without bark were obtained by summing the volumes of the 1-m sections whose individual volumes had been calculated with Smalian's formula (Avery 1967). A weighted linear regression, using a natural log transformation of the dependent variable, was employed to predict merchantable volumes with and without bark from d.b.h. and merchantable heights. The bias associated with the regression log-transformed data was ignored after tests with Baskerville's approximate correction (Baskerville 1972) resulted in very small changes. In addition, a "local" volume equation for merchantable bole volume with bark was developed using a polynomial model (with the dependent variables d.b.h. and d.b.h. squared). Green and dry weight relationships of the merchantable bole with bark was developed as follows. First, green- and dry-weight densities of the disks were used to calculate the weights of adjacent 1-m sections. Then a linear regression equation based on the weights, diameters, and heights on the tree of the disks sampled was employed to predict green and dry weights of the remaining 1-m segments. The calculated and predicted weights of the 1-m sections were summed to obtain the green and dry weights of each tree. These weights became the dependent variables in a linear model based on d.b.h., d.b.h. squared, and commercial bole length. A linear model was constructed to predict heartwood thickness from inside-bark diameter at any point on the bole and height at that point. Residuals were plotted for all the models constructed, and no obvious trends were noted. Because of the small sample size in each plantation, tests for differences of models between plantations were not conducted.

RESULTS

The following linear regression equations were used to construct the tables for commercial volume with bark (table 1) and commercial volume without bark (table 2) of mahoe:

$$\ln Vwb = -3.8699 + 0.1069D - 0.0006829D^2 + 0.04355L$$

$$n = 50;\ Sy.x = 0.1159;\ R^2 = 0.984$$

$$\ln Vwob = -4.0111 + 0.1053D - 0.0006568D^2 + 0.04426L$$

$$n = 50;\ Sy.x = 0.1266;\ R^2 = 0.981$$

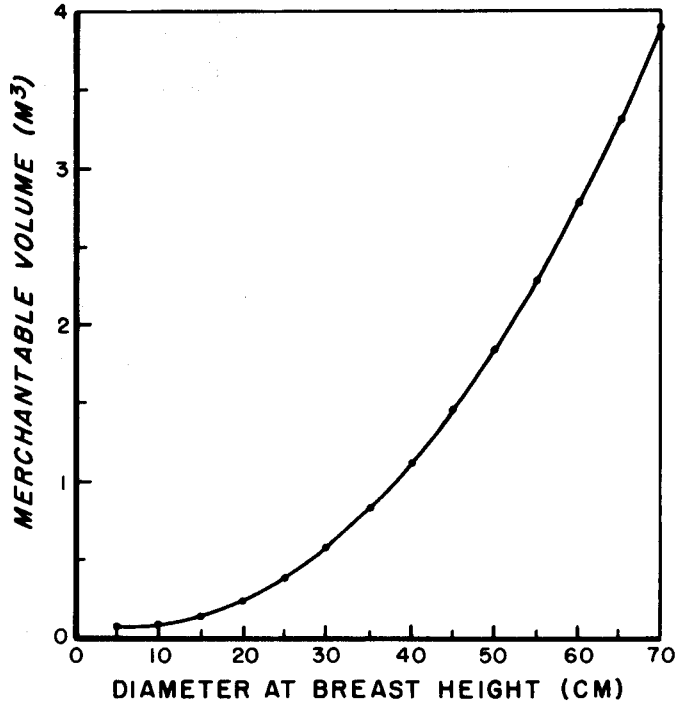

Figure 1.—*Graphical representation of the relationship between diameter at breast height and merchantable bole volume of mahoe* (Hibiscus elatus).

where:

ln Vwb = natural log of commercial volume with bark (m^3)
ln Vwob = natural log of commercial volume without bark (m^3),
D = d.b.h. (to the nearest 0.1 cm),
D^2 = d.b.h. squared,
L = merchantable bole length (to the nearest 0.1 m),
Sy.x = root mean square error, and
R^2 = multiple regression coefficient.

The graphical presentation (fig. 1) of a local volume equation is based on the relationship:

$$Vwb = 0.1112 - 0.01312D + 0.0009599D^2$$

$$n = 50;\ Sy.x = 0.1305;\ R^2 = 0.961$$

Both the green and dry weights of merchantable boles of mahoe presented in tables 3 and 4, respectively, are given by the following equations:

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$$Wg = 2.4372 + 0.1387D - 0.00113D^2 + 0.04244L$$

$$n = 50;\ Sy.x = 0.1330;\ R^2 = 0.980$$

$$Wd = 1.7850 + 0.1342D - 0.00107D^2 + 0.04506L$$

$$n = 50;\ Sy.x = 0.1372;\ R^2 = 0.979$$

where:

Wg = green weights of commercial boles (kg)

Wd = dry weights of commercial boles (kg)

The heartwood diameter within mahoe stems can be predicted by the relationship:

$$HD = -3.2082 + 0.9659Dib - 0.1904Hs$$

$$n = 187;\ Sy.x = 1.5910;\ R^2 = 0.969$$

where:

HD = heartwood diameter at any point on stem

Dib = diameter inside bark, and

Hs = height on stem.

In large diameter stem pieces, heartwood is well defined, richly colored, and occupies most of the stem thickness. In small stems and at the small diameters located high on merchantable stems, heartwood is light colored, poorly defined, and disappears altogether at around an 8-cm diameter.

The average stump height for the 50 trees cut was 0.28 ± 0.02 m. The variation appeared to be associated with tree size and topography; the higher stumps had a tendency to be found on larger trees and on steeper slopes.

Table 1.—*Cubic-meter merchantable stem volume (outside bark) of mahoe* (Hibiscus elatus)

D.b.h.	Merchantable bole length (m)													
	2	4	6	8	10	12	14	16	18	20	22	24	26	28
cm	*Cubic meters**													
15	0.10	0.11	0.12	0.13	0.14	0.15	0.16	0.18	0.19	0.21	0.23	0.25	0.28	0.30
20		0.16	0.17	0.19	0.21	0.23	0.25	0.27	0.30	0.32	0.35	0.38	0.42	0.46
25		0.23	0.26	0.28	0.30	0.33	0.36	0.40	0.43	0.47	0.51	0.56	0.61	0.67
30		0.33	0.36	0.40	0.43	0.47	0.51	0.56	0.61	0.67	0.73	0.79	0.87	0.94
35		0.45	0.50	0.54	0.59	0.64	0.70	0.77	0.84	0.91	0.99	1.08	1.18	1.29
40			0.65	0.71	0.78	0.85	0.93	1.01	1.10	1.20	1.31	1.43	1.56	1.71
45			0.84	0.91	0.99	1.08	1.18	1.29	1.41	1.54	1.68	1.83	2.00	2.18
50						1.34	1.46	1.59	1.74	1.90	2.07	2.26	2.46	2.69
55						1.60	1.74	1.90	2.07	2.26	2.47	2.69	2.94	3.21
60						1.84	2.01	2.19	2.39	2.61	2.84	3.10		
65							2.24	2.44	2.66	2.90	3.17	3.46		

*Block outline indicates general extent of basic data.

Table 2.—*Cubic-meter merchantable stem volume (inside bark) of mahoe* (Hibiscus elatus)

D.b.h.	Merchantable bole length (m)													
	2	4	6	8	10	12	14	16	18	20	22	24	26	28
cm	*Cubic meters**													
15	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.17	0.18	0.20	0.22	0.24	0.26
20		0.14	0.15	0.16	0.18	0.19	0.21	0.23	0.25	0.28	0.30	0.33	0.36	0.39
25		0.20	0.22	0.24	0.26	0.28	0.31	0.34	0.37	0.40	0.44	0.48	0.53	0.58
30		0.28	0.31	0.34	0.37	0.40	0.44	0.48	0.52	0.57	0.62	0.68	0.75	0.81
35		0.39	0.42	0.46	0.50	0.55	0.60	0.66	0.72	0.78	0.85	0.93	1.02	1.11
40			0.56	0.61	0.66	0.73	0.79	0.87	0.95	1.03	1.13	1.23	1.35	1.47
45			0.71	0.78	0.85	0.93	1.02	1.11	1.21	1.32	1.45	1.58	1.73	1.89
50						1.15	1.26	1.38	1.50	1.64	1.79	1.96	2.14	2.34
55						1.38	1.51	1.65	1.80	1.97	2.15	2.35	2.57	2.80
60						1.60	1.75	1.91	2.09	2.28	2.50	2.73		
65							1.97	2.15	2.35	2.56	2.80	3.06		

*Block outline indicates general extent of basic data.

Table 3.—*Green weights for merchantable boles of mahoe* (Hibiscus elatus)

D.b.h.	Merchantable bole length (m)													
	2	4	6	8	10	12	14	16	18	20	22	24	26	28
cm	*Kilograms**													
15	77	84	92	100	109	118	129	140	152	166	181	197	214	233
20	127	138	150	164	178	194	211	230	250	272	297	323	351	383
25		214	233	254	276	301	328	357	388	423	460	501	545	594
30		314	342	372	405	441	480	523	569	620	675	734	799	870
35		435	474	516	562	611	666	725	789	859	935	1017	1108	1206
40		570	621	676	735	801	871	949	1033	1124	1224	1332	1450	1579
45			768	836	910	991	1078	1174	1278	1391	1514	1649	1795	1954
50					1064	1159	1261	1373	1495	1627	1771	1928	2099	2285
55						1281	1394	1518	1652	1798	1958	2131	2320	2525
60						1338	1456	1585	1726	1879	2045	2226		

*Block outline indicates general extent of basic data.

Table 4.—*Dry weights for merchantable boles of mahoe* (Hibiscus elatus)

D.b.h.	Merchantable bole length (m)													
	2	4	6	8	10	12	14	16	18	20	22	24	26	28
cm	*Kilograms**													
15	38	42	46	50	55	60	66	72	79	86	94	103	113	124
20	62	68	74	82	89	98	107	117	128	140	153	168	183	201
25		105	115	125	137	150	164	180	197	215	235	258	282	309
30		152	167	183	200	219	239	262	287	314	343	376	411	450
35		211	230	252	276	302	331	362	396	433	474	519	568	621
40		276	302	330	361	396	433	474	518	567	621	679	743	813
45		342	375	410	449	491	537	588	643	704	770	843	922	1009
50					528	578	632	692	757	828	906	992	1085	1188
55						644	705	771	844	924	1011	1106	1210	1324
60						681	745	815	892	976	1068	1169		

*Block outline indicates general extent of basic data.

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